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## Properties of $X(3872)$ from hadronic potentials coupled to quarks

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We study the properties of the hadron-hadron potentials and quark-antiquark potentials from the viewpoint of the channel coupling[1]. We introduce the effective hadron-hadron potential with coupled to the quark channel.

As an application, we construct a coupled-channel model of  $c\bar{c}$  and  $D\bar{D}$  to describe exotic hadron  $X(3872)$ [2].

For the obtained nonlocal potentials, we apply two methods of the local approximation proposed previously, the formal derivative expansion and the derivative expansion in the HAL QCD method, by carefully examining the energy dependence of the potential.

We confirm that the local approximation by the HAL QCD method works better than the formal derivative expansion also for the energy-dependent potential. At the same time, we show that, in the HAL QCD method, the resulting phase shift is sensitive to the choice of the wavefunction to construct the local potential when the system has a shallow bound state such as  $X(3872)$ .

To investigate the internal structure of the  $X(3872)$ , we introduce the direct 4-point interaction of the hadron channel, in addition to the contribution of the coupling to the quark channel. We study the dominant component of the  $X(3872)$  by analyzing the wavefunctions, compositeness, and pole trajectories.

[1] I. Terashima and T. Hyodo, Phys. Rev. C 108, 035204 (2023).

[2] M. Takizawa and S. Takeuchi, PTEP 2013, 093D01 (2013).

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